

The influence of backflow on the switching speed of dual frequency liquid crystal

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Backflow is a well-known effect that limits the switching speed in vertical aligned liquid crystal displays. When voltages are applied exceeding a certain threshold voltage, the reorientation which is initially fast causes a flow that influences the director orientation in the middle of the cell. An optical bounce occurs as the liquid crystal in the middle of the cell temporally has a reverse orientation. Driving voltages should thus not exceed this threshold voltage or the switching speed (drastically) reduces [1]. Backflow also increases the relaxation time of cells with planar (or hybrid) alignment but optical bounces do not occur in this situation because the switching to the planar state is typically quite slow as it is driven by the interplay of elastic forces and boundary conditions.

Dual-frequency liquid crystals (DFLCs) can be switched in a voltage driven way from the planar state to the homeotropic state and back. This is because the liquid crystal exhibits dielectric anisotropy $\Delta\epsilon$ with different sign depending on the frequency of the applied voltage signal. For low frequency signals (1 kHz) $\Delta\epsilon$ is positive, while for higher frequency signals the $\Delta\epsilon$ is negative. In DFLC cells with planar alignment, it is possible to decrease the natural relaxation time (for going from the homeotropic state to the planar state) by applying a high frequency voltage over the substrates. In this way, the switching from planar to homeotropic is fast (sub-millisecond) as in the ordinary nematic LC cells. But in contrast to the ordinary nematic LCs, the switching from the homeotropic state to the planar state can also be fast (a few milliseconds).

Experimental switching measurements are carried out using a polarization microscope, photodiode and computer controlled data acquisition device for measuring the photodiode signal and generating the desired voltage waveform. These measurements have revealed that the switching time from the homeotropic state to the planar state exhibits a similar jump to longer switching times as in VAN cells when a certain threshold voltage is exceeded. The study of this threshold voltage however is more complicated than in VAN cells because the switching is not only determined by the high frequency voltage signal, but also by the amplitude of the low frequency signal that is used to switch the cell to the homeotropic state.

The experimental data is analyzed and compared with theoretical calculations based on a one-dimensional simulation model of the liquid crystal orientation [2]. The Navier-Stokes equations are combined with the Leslie-Ericksen theory and the Q-tensor formalism in order to simulate the switching behavior of DFLC for several configurations. The effect of backflow on the switching speed is investigated for full switching and switching between intermediate states of nematic and cholesteric DFLC cells. Optimal electric driving schemes and substrate anchoring conditions for fastest switching of DFLC and simulation results are compared with experimental data.

References:

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